FEASIBILITY ANALYSIS ON CAPACITOR BANK INSTALLED IN TENAGA NASIONAL BERHAD SUBSTATION

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A project report submitted in fulfilment of the
Requirements for the award of the degree of
Master of Engineering (Electrical-Power)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2012

Specially dedicated to my beloved mom and dad,
Leha bt. Mohd Noor and Wahab bin Abdul Rahman,
My siblings and family, for their encouragement and support;
As well as my beloved wife, Yuzlina bt. Mohd Napis, my kids Syahmi Harris and Nur Sarah Yasmin, and all my friends for their encouragement and motivated me along my excellent journey of education

ACKNOWLEDGEMENT

In the name of Allah, Most Gracious, Most Merciful, Praise be to Allah, the Cherisher and Sustainer of the Worlds. With His permission I have completed my Master Degree of Electrical Engineering (Power) and hopefully this works will benefit the development of the Ummah all over the world

I would like to express my sincere gratitude to my supervisor, Associate Prof. Dr. Mohd Wazir bin Mustafa, who has supported me throughout my work with his guidance, patience, motivation, enthusiasm and enormous knowledge whilst allowing me the room to work in my own way. I attribute the level of my Master Degree to his encouragement and effort which without him this report would not have been possible to be written and completed. It is an honor for me having this opportunity doing the project under his supervision.

It is a pleasure to thank those who made this project report possible and I would like to show my huge appreciations to my fellow colleagues and also En. Danial Mohd Noor for the motivation and moral support.

Last but not least, I owe my deepest appreciation to my beloved wife Yuzlina bt Mohd Napis, my father Wahab bin Abdul Rahman, my mother Leha bt Mohd Noor, my father in law Mohd Napis bin Mohd Shariff, my mother in law Kalsom bt, my son Syahmi Harris, my daughter Nur Sarah Yasmin and all my family for supporting me spiritually throughout my life.

ABSTRACT

Generally, reactive power is correlated with voltage in power system. In the high voltage substation, capacitor bank is used to increase back voltage that has been dropped due to high load or long transmission line used for transmitting electricity. In this work, it will describe in general on operation of capacitor bank in the system and details on analysis on performance of capacitor bank especially during failure of capacitor units or elements. In the capacitor bank design, it contains several capacitor units which have been arranged in specified configuration to provide reactive power to the system. A unit of capacitor bank itself contains many capacitor elements that provide capacitance value. There are many designs for arrangement of capacitor units and elements for capacitor bank by the Original Equipments Manufacturer (OEM). As usual, for any electrical equipment that installed in power system, it is protected with protection devices in order to avoid any damaged to the equipment during fault occurred. For failure of capacitor units or elements, it must be detected as well since it will contribute to the unbalance on capacitance value, current and voltage. There are two techniques of detecting failures of capacitor units or elements which are current and voltage techniques. In Tenaga Nasional Berhad (TNB) substation, current technique is most preferable since the lack of voltage technique which is easy influenced by voltage grid system. Two models of capacitor bank that have been installed in TNB substation presently are modeled in PSCAD software for performance analysis aligns with allowable voltage tolerance stated in IEEE Std 18-1992 and Std 1036-1992. As conclusion, based on performance analysis of capacitor bank during failure of capacitor units or elements, the design of arrangement for capacitor units is very important since the failure of capacitor unit or element will lead to unbalance current in capacitor bank. Furthermore, from the analysis, the numbers of failure capacitor elements which produces to unbalance in the system can be predicted so that alarm and tripping will be triggered to avoid further damages.

ABSTRAK

Secara umumnya, kuasa reaktif adalah berhubungkait dengan voltan pada sistem kuasa. Di Pencawang Voltan Tinggi, banka kapasitor digunakan untuk menaikkan semula voltan yang telah jatuh disebabkan beban tinggi atau penggunaan talian penghantaran yang panjang bagi menghantar elektrik. Di dalam kerja ini, ia akan menerangkan secara umum bagi operasi banka kapasitor di dalam sistem dan secara terperinci bagi analisis prestasi banka kapasitor terutamanya semasa kerosakan unit atau elemen. Di dalam rekabentuk banka kapasitor, ia mengandungi banyak unit kapasitor yang telah disusun dalam spesifik konfigurasi untuk membekalkan kuasa reaktif pada sistem. Satu unit kapasitor sendiri mengandungi elemen-elemen kapasitor yang membekalkan nilai kapasitan. Terdapat banyak rekabentuk bagi susunan unit atau elemen kapasitor untuk banka kapasitor oleh pembuat peralatan asal. Seperti lazimnya, bagi sebarang peralatan elektrik yang dipasang di dalam sistem, ianya dilindungi dengan sistem perlindungan untuk mengelakkan kemusnahanan peralatan semasa kerosakan berlaku. Bagi kerosakan unit atau elemen kapasitor, ianya mesti dikesan sebaiknya berikutan ia akan menyumbang kepada ketidakseimbangan nilai kapasitan, arus dan voltan. Terdapat dua teknik mengesan kerosakan unit atau elemen kapasitor iaitu teknik arus dan voltan. Di Pencawang Tenaga Nasional Berhad (TNB), teknik arus lebih dipilih berikutan kekurangan teknik voltan yang lebih mudah dipengaruhi oleh voltan sistem grid. Dua model banka kapasitor yang telah dipasang di dalam pencawang TNB ketika ini dimodelkan di dalam perisisan PSCAD untuk analisis prestasi selaras dengan voltan dibenarkan seperti dinyatakan pada Piawai IEEE 18-1992 dan Piawai 1036-1992. Kesimpulannya, berdasarkan analisis prestasi banka kapasitor semasa kerosakan kapasitor unit atau elemen, rekabentuk untuk susunan kapasitor unit adalah sangat penting berikutan kerosakan kapasitor unit atau elemen akan menyebabkan ketidakseimbangan arus banka kapasitor. Tambahan lagi, bilangan untuk kerosakan elemen yang menghasilkan ketidakseimbangan di dalam sistem boleh dijangka supaya penggera dan pelantikan akan beroperasi bagi mengelakkan kerosakan seterusnya.

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LIST OF SYMBOLS

P	-	Real Power
Q	-	Reactive Power
V	-	Receiving Voltage
E	-	Sending Voltage
C	-	Capacitance
δ	-	Angle of Sending Voltage
θ	-	Angle of Impedance
ϕ	-	Angle of Current
S_A	-	Sending Apparent Power
S_B	-	Receiving Apparent Power
μF	-	Micro Farad
Z	-	Impedance
X	-	Reactance
kVA	-	Unit of Apparent Power
kW	-	Unit of Active Power
kVar	-	Unit of Reactive Power
f	-	Frequency
R_1	-	Total Capacitance Red Left Bank
Y_1	-	Total Capacitance Yellow Left Bank
B_1	-	Total Capacitance Blue Left Bank
R_2	-	Total Capacitance Red Right Bank
Y_2	-	Total Capacitance Yellow Right Bank
R_2	-	Total Capacitance Blue Right Bank
I	-	Unbalance Current

LIST OF ABBREVIATIONS

Single-Y	-	Single Wye
Double-Y	-	Double Wye
PSCAD	-	Power System Computer Aided Design
TNB	-	Tenaga Nasional Berhad
SVC	-	Static Var Compensator
PF	-	Power Factor
IEEE	-	International of Electrical & Electronic Eng.
CT	-	Current Transformer
MS	-	Malaysia Standard

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, power system demand kept increasing from time to time aligns with development in every aspect of life. There will be a big responsibility and challenge to the utility company to deliver good quality service to the consumers including minimum interruption.

As basic principles of electrical power system, voltage profile can be controlled by reactive power management meanwhile frequency profile can be controlled by active power management. Hence, any requirement especially in case voltage fluctuation either low or high occurred, we can control by providing reactive power as needed. The sources for providing reactive power can be in many ways such as generators, capacitors and reactors.

Generally installation of capacitor bank in the substation is a device providing reactive power to the system in order to maintain nominal voltage which might drop due to high load and losses. In this project, more focus is given to analyze on failure on capacitor bank itself. The capacitor bank system should help power system grid but without proper design or poor knowledge and implementation on this, capacitor bank will become catastrophic to electrical engineer which might waste a lot of energy and money in order to maintain it, also increasing of risk factor due to explosion on any capacitor unit.

In this chapter, it will describe clearly on project background, problem statement, objectives on this project, scopes of the project and the methodology in order to achieve the targets. In addition, it also discusses generally on relation reactive power with voltage profile and application by utility company in Malaysia for providing reactive power to the system.

1.2 Project Background

Generally, the voltage in the substation plays a vital role in order to determine the reliability and availability supply to the customers. It must be monitored closely especially from the utility side so that provided voltage at the busbar is within tolerance given. Low voltage can contribute to bad performance on the electrical equipment meanwhile over voltage can contribute to over stress on the insulation and reduce life time of the equipment. In power system, electricity which generated from power station is transmitted via transmission lines to give supply at load centre. With consideration losses at transmission lines, it will affect voltage drop at the substation. Meantime, voltage drop can be happened when the substation is connected with heavy loaded area in example at industrial area. However, voltage can be higher and exceeding the limits during light load and at same time too many generator were in service.

As stated in basic electrical power system, a change in real power demand affects essentially the frequency meanwhile a change in reactive power affects mainly the voltage magnitude. It shows that voltage can be controlled with providing additional reactive power in the system. The sources of reactive power are generators, capacitors and reactors [9]. In the substation, capacitors are used widely to increase back the low voltage meanwhile reactors are used widely to reduce back over voltage in the system. Capacitor bank installation is more preferable might due to more economical and less maintenance compared with other devices such as Static Var Compensator (SVC).

Capacitor bank that has been installed in the substation should be working efficiently to provide reactive power in the system so that voltage profile can be controlled as well. Generally, capacitor bank is designed with series and parallel connection of several capacitor units. It also has been designed with selected system configuration such as Double Wye (Double-Y) Undergrounded System or Double-Y Grounded System. In this study, focus is given to Double-Y Undergrounded System since it has been used in Tenaga Nasional Berhad (TNB) Substation. Failures of capacitor bank due to capacitor units or elements are detected through protection devices installed in the system.

1.2.1 Reactive Power

With looking into reactive power system, an ideal case will show balance between existence of reactive power generated and reactive power requirement of the grid. If these two balance with each other then the voltage profile of the grid can be said ‘good’ [10].

When the balance between reactive power generated and reactive power required is disturbed, the voltage instability prevails causing voltage fluctuations [10]. In the simplest word, we can appreciate that:

Reactive generation < Reactive requirement = Low voltage

Reactive generation > Reactive requirement = Low voltage

Considering Figure 1.1 for modeling of power transfer and reactive power [10]:

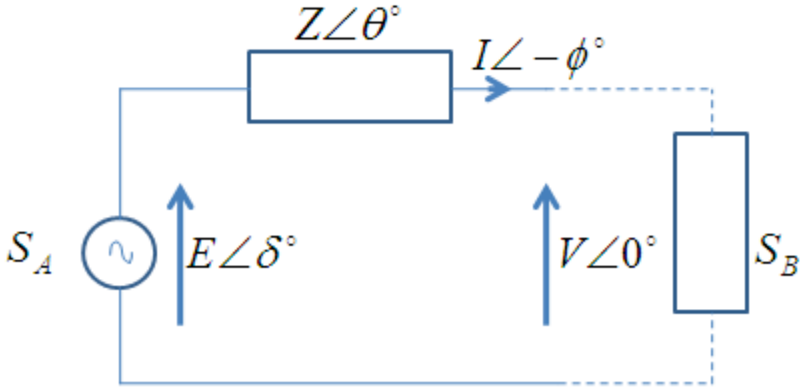

Figure 1.1: Modeling power system

From derivation, we can see voltage depends only on reactive power. The equations stated as below [10]:

$$E - V = \frac{XQ}{V} \tag{1.1}$$

$$E - V \propto Q \tag{1.2}$$

Where E = sending voltage

V = receiving voltage

Q = reactive power

X = reactance

1.2.2 Application in Tenaga Nasional Berhad (TNB) Substation

TNB is a utility company in Malaysia that supply electricity in Peninsular of Malaysia. Similarly with other utilities company in the world, TNB also has shown their concern about voltage magnitude especially in the substation. With same principles of electrical engineering applied to the system, TNB has used equipment in the substation to inject or absorb reactive power in order to control the voltage magnitude such as:

i. Installation of capacitor bank to increase dropped voltage

ii. Installation of reactor to compensate over voltage

iii. Installation SVC to increase dropped voltage and to compensate over voltage

1.3 Problem Statement

Capacitor bank is one of the common applications that have been used widely in the substation in order to increase the voltage drop. Capacitor bank is designed with many connection of capacitor unit instead only one connection capacitor unit. The reason capacitor bank is not designed with only one connection unit might due to the capability on design capacitor unit with high value capacitance and to minimize risk if one capacitor unit failure and contributed the whole capacitor bank to be out of service. A number of capacitor units are arranged with series and parallel connection to provide or inject reactive power to the system. In the high voltage substation, capacitor bank is installed and connected directly to the high voltage busbar.

There are several reasons can be listed out as root causes on the failure of capacitor bank from operating efficiently. One of that is the failure of capacitor units or elements which can cause capacitor bank to be out of service for certain period until the problems have been rectified. Basically, there are many designs with different total number of capacitor units and different arrangements of capacitor units. Protective relays have been installed in the capacitor bank bay so that any abnormalities can be sensed quickly and enable circuit breaker to isolate the system immediately. Nevertheless, the focus here is to determine the techniques to be used for detecting the failure of capacitor units.

1.4 Objectives

The main objectives of this project are as follow:

i. To review method of detecting unbalance system due to failure of capacitor unit

ii. To analyze unbalance current method as utilized in TNB system

iii. To simulate and evaluate the performances of capacitor bank design during failure of capacitor unit

1.5 Scope of the Project

The main scopes of this research are as follow:

i. Study and analysis is based on capacitor bank installed in TNB Substation (Configuration Double-Y Ungrounded)

ii. Analysis on technique or method of detecting on failure capacitor unit in capacitor bank system

iii. Simulation and analysis performance from two model of capacitor bank by using PSCAD software:

   a) Model A – had been installed at TNB Cheras Jaya 132kV Substation

   b) Model B – had been installed at TNB Bukit Jelutong 132kV Substation

1.6 Literature Review

In order to achieve the project objectives, the methodology is constructed with several stages as Figure 1.2. In literature review, the focus is to review the basic principles of capacitor bank design, principles and construction. The protection scheme for capacitor bank also has been reviewed for deep understanding on which protective relays should be operated during capacitor unit failed. Besides, the techniques for detecting failure of capacitor unit has been analyzed as well so that the principles can be clearly understood and applied in this research.

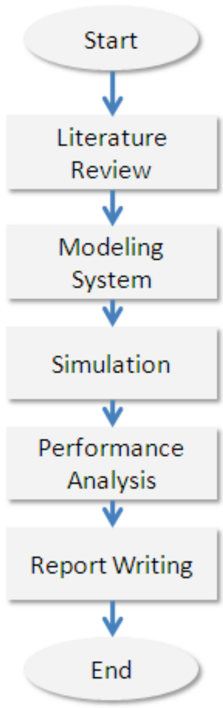

Figure 1.2: Flow chart of project methodology

1.6.1 Modeling System using PSCAD

There are two designed model of capacitor bank installed in TNB system. Both is using configuration Double-Y Connection. Both designs are modeled in PSCAD so that the performance for every design during failure of capacitor unit or elements can be determined.

1.6.2 Circuit Simulation

Both models of circuits are used for simulation using PSCAD/EMTDC software in order to analyze the performance of capacitor bank.

1.6.3 Performance Analysis

The performance for each design of capacitor bank during failure of capacitor unit or elements is analyzed and evaluated by creating some case study related to the failure.

1.7 Report Outline

Report writing is conducted in order to document the project's objectives, scopes, methodology and the results. All methodology involved is documented and explained in detail for understanding purposed.

This project report consists of six chapters. In Chapter 1, the project is elaborated clearly including the objectives and scopes of the project. In Chapter 2, the principles of capacitor bank have been discussed thoroughly for deeper understanding. It also described application capacitor bank at site for more understanding. In Chapter 3, the techniques for detecting failure of capacitor unit are discussed including modeling of the circuits and the formulas. In Chapter 4, the circuit modeled in PSCAD software for simulation meanwhile in Chapter 5 more discussed on result and the discussion. In Chapter 6, it is the project conclusion and recommendation for future works.

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